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THE CONTINUOUS HUB CONCEPT

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by

Trace Arley Weisenburger

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

ARIZONA STATE UNIVERSITY

August 1993

THE CONTINUOUS HUB CONCEPT

by

Trace Arley Weisenburger

has been approved

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Abstract

The focus of this study is on the continuous hub concept and its potential role in increasing airport capacity, without the use of larger aircraft, additional runways and more gates. The study of the current hub-spoke concept shows many inefficiencies exist. The continuous concept produces a more efficient aircraft schedule. This study demonstrates how the continuous hub concept can reduce airport congestion by spreading the demand evenly throughout the day.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

Aviation has progressed a long way since the 120-foot flight by Orville Wright on December 17, 1903, at Kitty Hawk, North Carolina, and since the first U.S. airline began operating between Tampa and St. Petersburg, Florida, on January 1, 1914. Over the past decade, commercial aviation has witnessed extraordinary growth. The number of passengers increased over 200 million between 1977 and 1987. Now the figure exceeds 500 million, and such trends are expected to continue over the next two decades. Passengers are expected to reach 800 million in the year 2000 and exceed a billion in 2010. However, airport construction has not kept pace with the increased demand. This indicates a need for greater airport capacity.

Capacity is a major problem facing airports today. If airport capacity is not increased, delays will result. For example, the air traffic delays due to the lack of airport capacity in the United States cost over five billion dollars in 1988 for excess fuel, time losses, etc. Losses of 10 billion dollars per year are expected by 1998 unless dramatic changes are made (Wise 1991). These losses put the airline industry in a crisis. Several major carriers have filed for Chapter 11 Bankruptcy or failed to survive.

Currently, the 27 busiest airports enplane approximately 74 percent of all passengers. The Federal Aviation Administration considers 13 large airports

congested and expects an additional 34 to experience significant delays by the year 2000 (United States 1989). A congested airport is an airport that, in any one season, is at or near full capacity, for at least 10 percent of its operating hours (United States 1989). Twenty-one airports exceeded 20,000 hours of annual delay in 1987. Table 1 shows the airports expected to exceed 20,000 hours of delay by 1997. Increased passengers, and reduced airlines are a direct cause of the congestion and delay at the major hub airports today.

The conventional solution to the lack of airport capacity is to construct either new airports or runways at the current congested airports. However, the prospects for increasing commercial airport capacity are limited. Due to high cost, public resistance, and local government regulations, new major airports, or expansions of existing airports, will be limited in the foreseeable future. The last major commercial airport built in the United States was Dallas-Fort Worth in 1973. Denver International is currently under construction and scheduled to open in Oct. 1993, at the expense of 2.4 billion dollars (Brown 1991). Denver International is planned to be the world's most efficient and largest airport covering over 53 square miles including eight runways. The airport is being constructed in the face of public resistance and government regulations

(Brown 1991). A myriad of obstacles had to be conquered before the project could even begin.

Table 1.

Airports expected to exceed 20,000 hours of delay by 1997.

AIRPORTS	1987 HOURS	1997 PROJECTED HOURS
(Thousand Annual hours Delay)		
ATL Atlanta Hartsfield	75-100	100+
BOS Boston Logan	20-50	20-50
CLE Cleveland Hopkins	10-20	20-50
CMH Port Columbus	10-20	20-50
CVG Greater Cincinatti	10-20	20-50
DCA Washington National	20-50	20-50
DEN Denver Stapleton	50-75	100+
DFW Dallas-Ft Worth	75-100	75-100
DTW Detroit-Wayne County	20-50	20-50
EWR Newark Intl.	20-50	75-100
HNL Honolulu Intl.	20-50	20-50
HOU Houston Hobby	10-20	20-50
IAD Washington Dulles	20-50	50-75
IAHHouston Intercontinental	20-50	20-50
JFK New York Kennedy	20-50	50-75
LAS Las Vegas McCarran	10-20	20-50
LAX Los Angeles Intl.	50-75	75-100
LGA New York LaGuardia	20-50	50-75
MCO Orlando Intl.	10-20	20-50
MEM Memphis Intl.	10-20	20-50
MIA Miami Intl.	20-50	75-100
MSP Minneapolis-St.Paul	20-50	20-50
ONT Ontario Intl.	10-20	20-50
ORD Chicago O'Hare	100+	100+
PHL Philadelphia Intl.	20-50	50-75
PHX Phoenix Sky Harbor	20-50	50-75
PIT Greater Pittsburgh	20-50	20-50
SEA Seattle-Tacoma	10-20	20-50
SFO San Francisco Intl.	20-50	50-75
SJC San Jose Intl.	10-20	20-50
SLC Salt Lake City Intl.	10-20	20-50
STL St Louis Lambert	20-50	50-75
TPA Tampa Intl.	10-20	10-20

Note: Chart is based on the Standardized Delay Reporting System from three major carriers. Predictions for 1997 assume approved airport improvements made. Prediction for Denver in 1997 assumes no new airport.

Source: FAA Office of Aviation Policy and Plans

Everyone seems to want adequate air transportation facilities, but not necessarily "in their backyard." The environmental considerations that accompany development of new airports have been extremely difficult to contend with, and in many cases nearly impossible. Political obstacles with high capital investment costs are a hindrance as well (Gesell 1992).

An alternative to building new airports, or expanding existing ones, is to improve the efficiency of the scheduling schemes currently in use. The hub-and-spoke system is the strategy the air carriers use to maximize profits. The hub-and-spoke system of scheduling and marketing establishes a number of routes connected to a central hub. Passengers are collected from feeder flights in smaller cities, transferred to other carrier flights in larger cities (the hub), and then transported to their ultimate destination. The traditional connecting hub entails airlines purposely scheduling resources, aircraft, and ground staff to converge at the hub-site during a short time period. At other times of the day, the hub-site is largely dormant. The current system has resulted in tightly scheduled arrivals and departures, which is a major contributor to the delay (United States 1989). The hub-and-spoke system, as currently structured, must be modified to achieve higher efficiencies. The majority of traffic during hub-site rush hours are due to decisions made by the

airlines to concentrate these resources during certain periods. There are too many airplanes voluntarily scheduled to arrive at the hub airport within a short time interval, so connecting flights can be accomplished. Figure 1 shows the daily distribution of arrivals and departures at Dallas-Fort Worth. At several time periods, the airport is operating near capacity. In addition, Figure 1 demonstrates American Airlines as the major contributor to the flows during the peak periods.

Aircraft arrivals and departures clustered into short time periods put a tremendous burden on both the airports and airlines. The delays shown in Table 1 result from congestion during peak flows. It is important to try to mitigate the extreme stresses the demand peaks put on airport facilities (Federal Aviation Administration AC150/5070). Launching 30 aircraft within five to ten minutes causes excessive taxi waits and delays. However in between the peak times, there are significant periods when the airport is operating below capacity. The problem, therefore, is not runway capacity but scheduling decisions to flow aircraft into and out of these airports within specific periods of the day (Lewis 1992). Studies of aircraft use in a connecting-hub system could show where inefficiencies exist, and where new capacity is really needed.

The airline industry is constantly evolving. Several factors drive changes in the nation's future air transportation system. These include the increasing air traffic, reduction in number of carriers, and revision in the components of airline cost structure. These factors point to the potential value of scheduling schemes such as the continuous hub concept which varies from today's hub concept.

To date, the accepted solution to airport capacity has been simply to build more airports or expand existing ones. This in itself will not solve the problem. The capacity challenge cannot be addressed successfully unless done so within the context of its user base, namely the dynamics that will shape the airline industry in the years ahead.

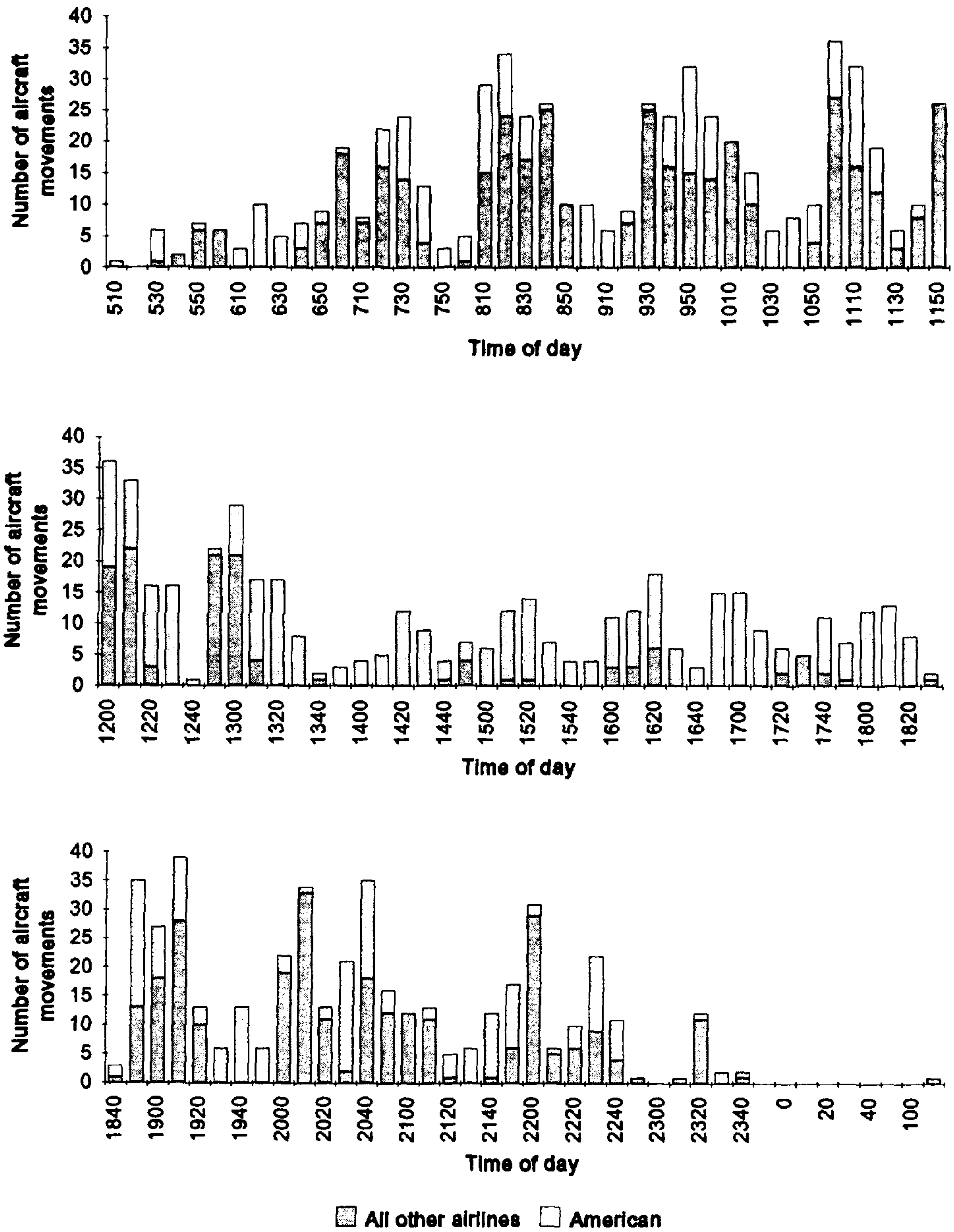

Figure 1
Average number of departures and arrivals
on a daily basis at Dallas-Fort Worth

2. AIRPORT CAPACITY

Airport capacity can be defined in many ways due to many variables which need to be considered. Runway lengths, taxiways, noise abatement, curfews, environmental constraints and the ability to accommodate traffic exiting runways at high speed all affect airport capacity (Hudlow 1988). One definition, referred to as practical capacity, is the number of operations during a specified interval of time corresponding to a tolerable level of average delay (Horonjeff 1983). Another definition referred to as "ultimate capacity", is the maximum number of aircraft operations that an airport can accommodate during a specified interval of time when there is a continuous demand for service (Douglas Aircraft Co 1973). The continuous demand for service means that there are always aircraft ready to take off or land (Horonjeff 1983). Figure 2 illustrates the relationship between delay-related and ultimate capacities.

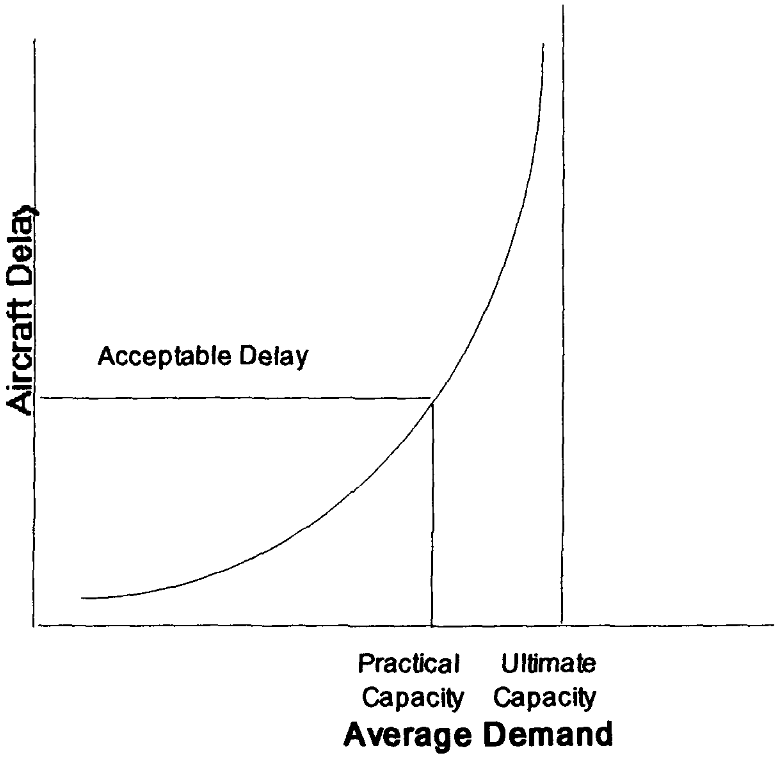

Figure 2

Relationship between delay-related and ultimate capacities

In the field of aviation it is virtually impossible to have a continuous demand throughout the operating period of the system (Horonjeff 1983). If a continuous demand was provided, delays would deteriorate the quality of service. When demand approaches ultimate capacity, delays to aircraft build up very rapidly (Horonjeff 1983). An important difference in these two measures of capacity is that practical capacity is defined in terms of delay and ultimate capacity does not consider delay.

There are several reasons for considering two definitions of capacity. Delays differ at all airports due to there airfield components because constraints differ from airport to airport (Horonjeff 1983). For a uniform standard to exist, "ultimate capacity" reflects the capability of the airfield to accommodate aircraft during peak periods of activity. This definition does not measure the magnitude of congestion and delay. Delay is greatly influenced by the pattern of demand (Horonjeff 1983). As an example, when several aircraft wish to use the airfield at the same time, the delay will naturally be larger than if they were spaced an interval of time apart. Therefore, the shape of the curve in Figure 2 is influenced by the pattern of demand (Horonjeff 1983). If schedules can be manipulated to produce a more uniform demand pattern, the practical capacity is increased without increasing ultimate capacity (Horonjeff 1983). This study examines the aspects of

providing more uniform demand patterns to increase practical capacity.

Practical airport capacity can be determined by using the Federal Aviation Administrations publication AC150/5060-5 "Airport Capacity and Aircraft Delay" (Federal Aviation Administration 1985). Airport component hourly capacities vary throughout the day due to variations of runway use, aircraft mix, ATC rules, etc., therefore, a number of calculations are needed to determine an airport's capacity. Calculating airport capacity and average delay per aircraft is derived from computer models used by the Federal Aviation Administration (FAA) and compiled in AC150/5060-5. Using AC150/5060-5 and Dallas-Fort Worth's configuration, practical capacity was determined to be 35 operations per 10 minute interval under Visual Flight Reference (VFR) conditions, and 20 operations per 10 minute interval under Instrument Flight Reference (IFR) conditions. These figures were used in the evaluation of the volume versus capacity later in this paper. However the actual capacity of Dallas Fort Worth is somewhat higher due to many extraneous variable unique to each airport.

Daily capacity based on a 20 hour workday, yields 2400 operations per day. The traditional system is yielding at 1500 operations per day. Capacity can be increased, but only if the arrival and departures are spread throughout a

wider time range throughout the day eliminating the peaks that connecting banks cause.

The results could allow the hub to accommodate 62% more traffic under optimal conditions. Airlines under any scheduling concept, continuous or traditional, could use this extra capacity. Improvements in efficiency can be attained over the traditional system of complexing connections.

3. BACKGROUND ISSUES

Continuous hubbing is not a new concept, it was researched earlier at a time when the industry dynamics would not support such a concept (ASRC 1992). Until recently, however, it was an approach that had only limited application. The continuous hub system is currently in use at two hub-site airports by Southwest Airlines. New solutions to airport capacity are needed, but this does not mean that new solutions can only come from new concepts.

Before deregulation hubs served passengers transferring between airlines. Since deregulation airlines have developed their individual hubs to capture the transferring passengers. In the early 1980's, there were many airlines operating out of many hubs. This prevented the development of the critical mass of transfer passengers needed for the continuous concept. With the demise of many airlines, passenger concentrations are increasing at the remaining hubs. Thus, the continuous concept may be viable at this time.

Growing Passengers

The number of passengers will continue to grow in the years ahead, but enplanement growth will be a factor of how airline's route passengers. A "passenger" is an individual who makes a trip, while an "enplanement" is what the passenger does on the trip. A single passenger may make one, two, or even more "enplanements" on a single trip (ASRC

1992). The general population is growing at a rate of 1.8% yearly, and if the passengers were to grow at this same rate, then a multiplier effect would occur to the enplanements (ASRC 1992).

Hub Reduction

The reduction in the number of hub sites also needs to be considered. US Air's hub at Dayton is being eliminated, and Northwest left Memphis. However, the nation has not suffered traffic loss as a result of these moves (ASRC 1992). The traffic was merely re-distributed over the other hubs. Strategic planning on the part of the airlines made these changes work (ASRC 1992). The number of large traditional hub-sites is decreasing while traffic is increasing. However, increasing demand at fewer hubs has increased congestion.

Airline Reduction

The airline industry is in crisis. Several major carriers have filed for Chapter 11 Bankruptcy or failed to survive. The United States has fewer airlines today than ten years ago. American Airlines announced on October 16, 1992 to lay-off between 500-1000 managers to compete more effectively with low-cost airlines. This announcement shows the nations largest airline is taking very aggressive steps to compete (Associated Press 1992A). The third quarter of 1992 brought large losses to the nations largest carriers. American lost 166 million dollars, while Delta lost 180

million, and United 95.1 million (Associated Press 1992A). The remaining carriers have serious challenges to face. It is highly possible that some of the major airlines may not recover from bankruptcy and the deep financial crisis that has afflicted the carriers in recent years.

Increased Flight Frequency

Increasing traffic, fewer carriers, and the reduction of hub sites requires increasing the passenger frequency, or velocity, at the hub sites (ASRC 1992). The basic result will be more passengers flowing through fewer hubs; therefore, increasing flight frequency at the remaining hubs during the entire day.

More passengers traveling on fewer airlines through fewer hubs requires the airlines to improve schedule efficiency to accommodate the higher passenger flows. Higher concentrations of passengers throughout the day will occur at the hub-site. The challenge is to carry these additional passengers as efficiently as possible. Using the current hub-spoke system requires larger aircraft, more gates, and additional runway and taxi way capacity. All three are expensive (ASRC 1992). However, a continuous concept can support more units of capacity operating during a wider time range throughout the day.

The changes in the structure of the airline industry changed the effectiveness of the continuous concept. Conditions of the 1980's did not support the continuous hub

concept. Recent changes in the airline industry may now justify the concept on a much wider scale for larger carriers.

4. ANALYSIS OF THE TRADITIONAL HUB-SPOKE SYSTEM

For the U.S. airlines to start a more prosperous and productive era, several elements must be addressed. A new, more efficient aircraft and a tight grip by airline management on costs are two such elements (Ott 1992). Cost controls are a major dilemma in today's hub system because several inefficiencies occur due to excess staffing, extra facilities, pacing, slot control, and schedule inflexibility.

Excess Staffing

Peak periods that occur in the hub-spoke scenario, require staff to meet peak demands. At other times the staff are not effectively working. Reducing the peaks will in turn reduce the staffing needed.

Extra Facilities

Facilities are designed to handle the peak periods; therefore, during non-peak times the facilities are idle and inefficient. With lower peak periods, fewer facilities are required to handle peak demand.

Pacing

Pacing occurs when the airline schedules flights to meet in connecting banks at the hub. Several cities may be one hour away, while others may be three hours away. Therefore, the airline must schedule the departure times back into the hub so that all aircraft meet for the scheduled bank. This requires aircraft at closer stations

to remain on the ground to coordinate with flights from the longer spokes. Hence, the aircraft are not fully utilized and money spent on leasing and high ownership costs raise the airlines overall operating expenses (ASRC 1992).

Slot Control

Slot Control is "the airport" scheduling a particular airline into specific time slots for arrivals and departures. This scheduling concept brings higher congestion at these specific times so the airline can fully maximize their landing rights at the airport. The landing rights raise operating costs and bring greater congestion to the airport, due to holding and taxi waits.

Schedule Inflexibility

The traditional scheduling system can be defined as the art of designing system-wide flight patterns that provide optimum public service, in both quantity and quality, consistent with the financial health of the carrier (Wells 1989). The public service and economic aspects of scheduling must be balanced with other factors, including:

1. Equipment maintenance. Each aircraft requires a separate maintenance plan. Airplane maintenance requires equiping certain stations with maintenance check facilities. Concentration of maintenance at only a few stations is desirable. Under continuous scheduling these maintenance checks are allocated at a single station.

2. Crews. All captains, first officers, flight engineers, and flight attendants need adequate rest between flights and training on each type of airplane. The continuous system has the same requirements, however training can be minimized, with the crew regularly flying the same aircraft.

3. Facilities. Gate space on airport ramps must be adequate for the schedule. Terminal capacity, including ticket counters, baggage-handling areas, and waiting rooms need to be adequate.

Sometimes aircraft must be flown virtually empty from one city to another late at night or early in the morning to have the plane ready to meet a rush hour demand. These positioning flights certainly affect the average load factor. The continuous concept does not require positioning flights.

4. Other factors. Weather can greatly effect the scheduling system. Weather creates delays, causing missed connections requiring many other schedule changes. The continuous schedule does not rely on connecting banks, leaving no chain reaction and schedule changes system wide. Delays which do occur under the continuous system have a limited impact because of reduced peak flows.

5. CONTINUOUS HUB CONCEPT

Continuous hubbing is a scheduling concept where aircraft route into and out of hubs based on block times and minimum turn times between the hub and serviced cities. Block time is the scheduled time required for a gate to gate operation. The aircraft might return to the same hub, or route on to another of the airline's hubs. No flights are scheduled into connecting banks or into any sequence. The continuous hub concept is distinctly different from the hub-spoke concept because schedules are developed, based on block times, not connecting banks. The continuous hub concept can be used when passenger flow at a given hub-site is at a level where passengers are flowed through the hub in large volumes and in flight frequency which makes specific-period connecting banks unnecessary (ASRC 1992). The increased frequency allows for more connection opportunities. Justifying higher frequency requires either increased passenger flow or a shift in the aircraft fleet to smaller aircraft.

In the continuous concept the airline does not attempt to time aircraft for specific connections nor for specific departure times. Therefore, a hub-site may have several aircraft arriving and departing in the same time frame, but far fewer than would be the case under the traditional scenario. Connection is random, yet greater flight frequency offers more opportunities than under the current

system. Continuous hubbing would likely result in some peaks and valleys, but much less pronounced than with the traditional system.

6. CONTINUOUS HUB CRITERIA

Criteria needs to be met for the continuous hub concept to be successful (ASRC 1992).

Established Presence

A large established presence at the hub-site airport, with a large (origin and destination) traffic, and a large investment already in the airport facilities is necessary. These factors indicate the airline would have at least 200 departures daily at the hub-site.

Catchment Basin

A strong catchment basin within 2.5 flying hours or 600 miles is necessary. Large population centers within this area will allow for a strong traffic flow to the hub site.

Large Population Base

A population base of at least 2 million at the hub will also help increase the traffic flow at the hub-site.

Small Efficient Aircraft

The best way to explain the need for small efficient aircraft is to show an example. Ex: Under the traditional system flying 500 passengers daily on 2 flights requires a 250 seat passenger jet. If the operating cost per flight for a 250 seat passenger jet is, for example 1,000 dollars, then total operating costs for this destination is 2,000 dollars per day.

Under the continuous system to fly the same 500 passengers, 5 flights are required with a 100 seat passenger

jet. For operating cost to be the close to the same as under the previous system requires each 100-seat jet flight to operate at 400 dollars, yielding an operating cost of 2,000 dollars per day.

Spreading the passenger flow over a wider time range, the continuous concept calls for more trips a day, but in smaller doses, than previously. Increasing trip frequency without increasing the number of passengers requires smaller efficient aircraft to reduce operating costs.

7. EXISTING CONTINUOUS HUB OPERATIONS

Southwest Airlines is an example of an airline using the continuous concept (ASRC 1992). Southwest schedules large numbers of flights continuously into and out of their hub-sites. They serve large metro areas with a strong local (origin and destination) markets, such as Phoenix and Dallas-Fort Worth. They only use 737's, and their hubs are within strong catchment basins. The Associated Press stated on August 7, 1992 that Southwest Airlines is the only major carrier to keep making money through the industry's recent financial turbulence (Associated Press 1992B). While Delta, American and United recorded large losses in the third quarter of 1992, Southwest announced a 26.9 million dollar gain (Associated Press 1992C). This demonstrates the viability of the continuous hub concept.

Using the continuous concept, one would expect with such little turn time that aircraft would be late and never on time, resulting in lost baggage. However, Southwest Airlines posted the best "on-time" performance in July of 1992. Southwest had 94.4 percent of their 1300 daily flights arrive on time in July, compared to the industry average of 79.8 percent. The airline also broke the on-time performance record in April and June of 1992. Southwest scored a performance "Triple Crown" in July of 1992 by also having the fewest reports of mishandled baggage and least customer complaints. The report showed 3.71 bags mishandled

for every thousand customers, compared to the industry average of 5.99 (Tribune 1992).

Apart from a stripped-down service, Southwest is successful in keeping its costs low by aircraft scheduling. Little or no "complexing" occurs. Aircraft are scheduled almost continuously and randomly into the hub-sites. Figure 3 displays the current Southwest schedule distribution at Phoenix. This schedule does not have the large peaks such as those at Dallas Fort Worth where the connecting bank schedule system is used. To a large extent, Southwest's financial success can be attributed to their application of the continuous concept. The challenge is to see if the concept can work on a wider level, by large full-service carriers.

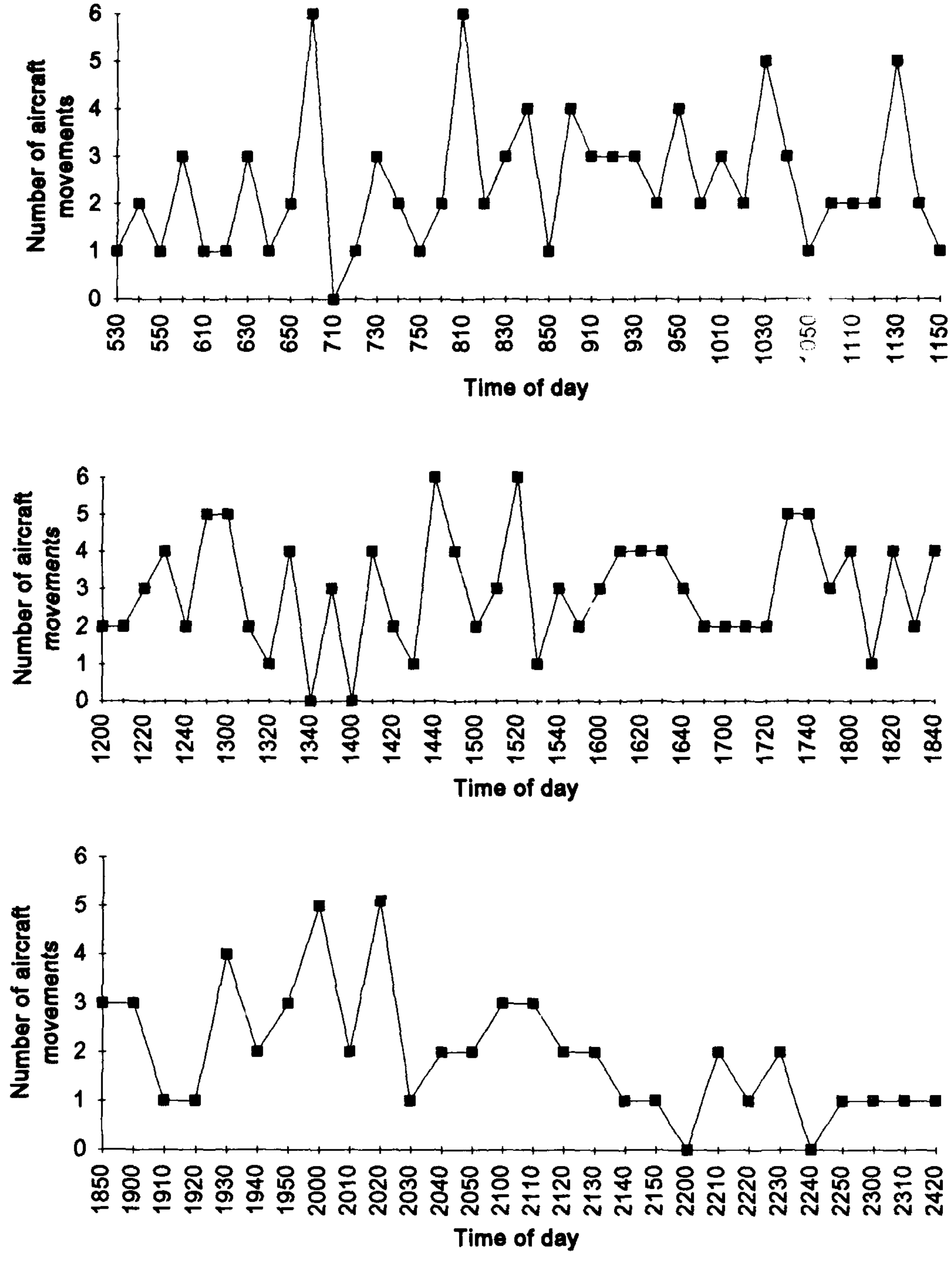

Figure 3
Southwest Airlines Traffic Distribution at Phoenix

8. CONTINUOUS HUB ANALYSIS

The potential risks and benefits of the continuous hub concept were evaluated by modeling American Airlines operations at Dallas-Fort Worth under the continuous hub concept. Initially, the existing fleet of the airline was used in the analysis. Subsequently opportunities for improving efficiency by reducing aircraft size was examined. The continuous hub concept model was constrained by requiring it to provide at least the same number of seats per day to all connecting airports as is provided under the existing system. In addition, the model was constrained by requiring the maximum connecting time between flights to be less than 90 minutes.

American Airlines encompasses 102 destination cities from the Dallas-Fort Worth hub. American uses two terminals totaling 54 gates (AMR 1992). Dallas-Fort Worth is located in a large metropolitan area of Texas with a population of over 4 million (ASRC 1992).

American Airlines meets the essential criteria as mentioned previously to form a continuous hub. Dallas-Fort Worth is an existing hub-site with a strong local (origin and destination) traffic. The catchment basin within 600 miles has a population of over 43 million (ASRC 1992). Figure 4 shows American Airlines destinations from Dallas-Fort Worth.

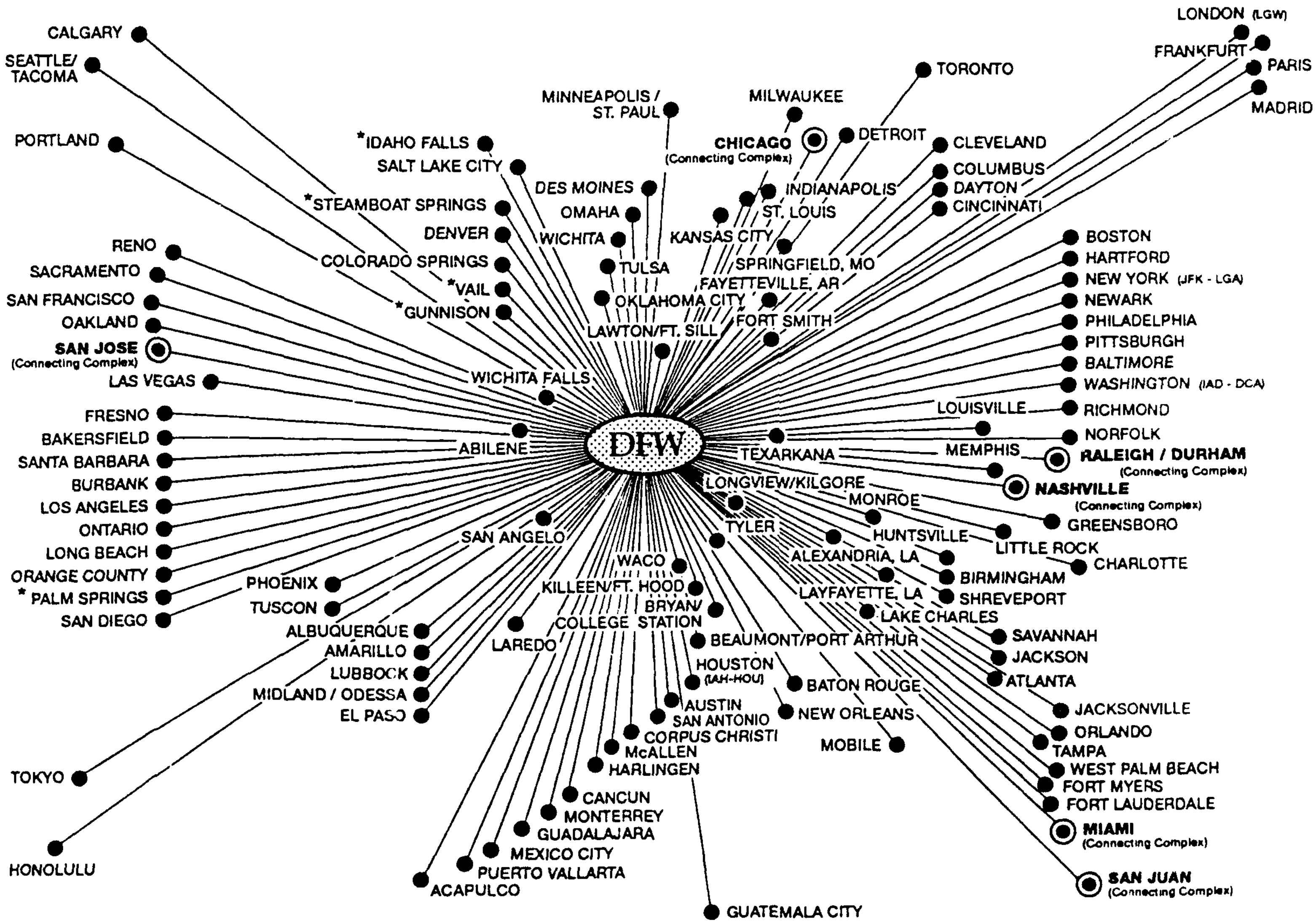

Figure 4
American Airlines Destinations from Dallas-Fort Worth (AMR 1992)

9. SCHEDULE CRITERIA

The peaks that occur in the traditional hub-spoke are evident, as shown in Figure 1. In addition, Figure 1 demonstrates American Airlines as the major contributor to the flows during the peak periods. The changeover to a continuous hub system by American Airlines will distribute their peaks and the valleys, increasing the practical airport capacity and airline efficiency. A schedule was developed by assigning one aircraft to each city served by American Airlines from Dallas-Fort Worth. This aircraft was cycled throughout the day to the specific destination using minimum turn times and block times (Appendix B). The criteria applied in developing the schedule are:

1. Aircraft were scheduled using block time plus "minimum turn times" (the minimum amount of time it takes for the airline to unload, load, and service the aircraft).
2. Minimum turn time was computed as 15 minutes at outstations, and 20 minutes at the hub. These turn times may not be entirely correct resulting in minor alterations to the schedule representing a level of sophistication beyond what could be accomplished in this research.
3. Each aircraft cycles between the designated spoke city and Dallas-Fort Worth.
4. No accommodation was made specifically to time flights into any sequence or into any connecting banks.

5. Other airlines at Dallas-Fort Worth are assumed to continue with their existing operations. However if American Airlines implemented the continuous concept, competitors would probably follow, benefiting the airport and the airlines.
6. The schedule is designed for 20 hours of operation per day.
7. Impacts of schedule changes at other airports are not considered. This should not cause a large problem, since the continuous system will also reduce the peaks at the hub airports and allow for better service at non hub airports.
8. The aircraft are scheduled into and out of the hub from the same spoke. They do not go "through" the hub.
9. When one aircraft provided a seat capacity less than the existing passenger capacity, from Table 2, a second aircraft was added to the route. Seat capacity was determined from American's Timetable dated June 15, 1992 to each destination. Therefore, seat capacity to each destination was not decreased.
10. If cycling an aircraft between the hub and one city provided excess passenger capacities as indicated in Table 2, two options were evaluated: 1) route the aircraft onto another city before returning it to the hub-site, and 2) alter the fleet mix and change the aircraft size to meet the passenger demand.

11. If connection times for flights between any pair of cities exceeded 90 minutes, a second aircraft was added.

10. SCHEDULE RESULTS

Table 2 displays the seat capacity and other statistics to each spoke city under the traditional system. Continuous departures were calculated to each spoke city from the developed schedule and displayed in Table 2. The seats per departure were calculated and were the basis for the plane provided in the continuous scenario. The smallest available jet was assigned to each spoke city based on the available seats per aircraft from Table 3. The passenger capacity of the proposed schedule equals or exceeds the existing schedule. The meaning of the headings in Table 2 are:

City Served: The abbreviated spoke city.

Trad Seats: The seats currently offered by American to the spoke city.

Miles to city: The distance to each spoke city by air.

Block Time: The time to fly to each city served including taxi time.

Trad dep: Current scheduled number of departures to each spoke city.

Basic dep: Number of departures based on one plane cycling throughout the day to the spoke city.

CH Extra: Number of extra departures times due to additional planes cycling to the spoke city to supplement the seat capacity.

CH Total: Total number of departures.

Seats/dep: Trad Seats/CH Total.

Added planes: Planes added to supplement the seat capacity cycling throughout the day where needed.

Plane provided: Smallest available jet to provide seat capacity for the seat/dep.

Table 2

Aircraft used for each city served

City served		Trad seats	Miles to city	Block Time	Trad dep	Basic dep	CH Extra	CH Total	Seats/ dep	Added Planes	Plane provided
ABQ	Albuquerque, NM	922	569	1.7	6	3	5	8	115	1	727-100
AMA	Amarillo, TX	595	313	1.17	7	6		6	99		F100
ATL	Atlanta, GA	994	731	2	7	3	4	7	142	1	S80
AUS	Austin, TX	1293	183	0.87	9	8		8	162		767-200
BFL	Bakersfield, CA	284	1271	3.07	2	2		2	142		S80
BWI	Baltimore, MD	694	1216	2.97	4	2	3	5	139	1	S80
BHM	Birmingham, AL	568	597	1.65	3	4		4	142		S80
BOS	Boston, MA	1008	1561	3.55	5	1	6	7	144	2	S80
BUR	Burbank, CA	426	1232	3	3	3		3	142		S80
YYC	Calgary Canada	426	1523	3.73	3	1	3	4	107	1	727-100
CUN	Cancun, Mexico	300		1.62	2	4		4	75		F100
CLT	Charlotte, NC	568	936	2.42	4	2	3	5	114	1	727-100
ORD	Chicago,IL	2987	801	2.25	16	3	15	18	166	4	767-200
CVG	Cincinnati, OH	478	811	2.12	2	3		3	159		727-200
CLE	Cleveland, OH	568	1021	2.67	4	2	5	7	81	1	F100
COS	Colorado Springs, CO	426	593	1.75	3	3		3	142		S80
CMH	Columbus, OH	568	926	2.35	3	3		3	189		757
CRP	Corpus Christi, TX	852	354	1.2	6	6		6	142		S80
DAY	Dayton, OH	284	861	2.25	2	2		2	142		S80
DEN	Denver, CO	1428	645	1.92	10	3	8	11	130	2	S80

Table 2 (cont.)

City served		Trad seats	Miles to city	Block Time	Trad dep	Basic dep	CH Extra	CH total	Seats/ dep	Added planes	Plane provided
DSM	Des Moines, IA	410		1.87	3	3		3	137		S80
ELP	El Paso, |TX	876	553	1.47	6	4		4	219		767-300
FLL	Ft. Lauderdale, FL	300	1118	2.82	2	2		2	150		727-200
RSW	Fort Myers, FL	300	1008	2.5	2	2		2	150		727-200
FAT	Fresno, CA	268	1313	3.17	2	3		3	89		F100
GSO	Greensboro, NC	426	998	2.43	3	3		3	142		S80
HRL	Harlingen, TX	568		1.34	4	4		4	142		S80
BDL	Hartford, CT	426	1470	3.35	3	1	3	4	107	1	727-100
HNL	Honolul, HI	582	3784	6.83	2	1	1	2	291	1	DC10
HOU	Houston, TX	2932	224	1	20	6	15	21	140	2	S80
HSV	Huntsville, AL	568	602	1.73	4	4		4	142		S80
IND	Indianapolis, IN	450	762	2.13	3	3		3	150		727-200
LitJan	Littlerock AR,Jackson	563		2.7		3		3	188		757
JACLBB	Jackson Hole,Lubbuck	773		2		4		4	193		757
JAX	Jacksonville, FL.	268	918	2.28	2	2		2	134		S80
MCI	Kansas City, MO	994	459	1.5	7	4	6	10	99	1	F100
LAS	Las Vegas, NV	1448	1056	2.55	6	3	3	6	241	1	MD11
LIT	Littlerock, AR	600	303	1.34			7	7	86	1	F100
LGB	Long Beach CA	426		2.95	3	3		3	142		S80
LAX	Los Angeles, CA	2510	1235	2.92	11	3	10	13	193	3	757
MAD	Madrid Spain	241	4965	9.67	1	1		1	241		MD11

Table 2 (cont.)

City served		Trad seats	Miles to city	Block Time	Trad dep	Basic dep	CH Extra	CH total	Seats/ dep	Added planes	Plane provided
MFEMTY	McallenTx, Monterrey, Mex	812		2.42		3		3	271		A300
MEM	Memphis, TN	518	431	1.38	4	4		4	130		S80
MEX	Mexico City Mex.	668	935	2.32	5	2	4	6	111	1	727-100
MIA	Miami, FL	1237	1120	2.73	8	3	5	8	155	2	727-200
MAF	Midland, TX	595		1.33	7	6		6	99		F100
MSP	Minneapolis St Paul MN	852	852	2.32	6	3	4	7	122	1	727-100
BNA	Nashville, TN	1270	631	1.68	8	3	5	8	159	1	727-200
MSY	New Orleans, LA	884	447	1.5	5	5		5	177		767-200
OAK	Oakland, CA	426	1457	3.37	3	2		2	213		767-300
OKC	Oaklahoma City, OK	1452	175	0.93	10	6	7	13	112	1	727-100
OMA	Omaha, NE	544		1.75	4	4		4	136		S80
ONT	Ontario, Ca	710	1189	2.75	5	2	3	5	142	1	S80
SNA	Orange County, CA	980	1205	2.93	5	2	3	5	196	1	757
MCO	Orlando, FL	592	983	2.53	5	2	3	5	118	1	727-100
ORY	Paris France	241	4949	9.42	1	1		1	241		MD11
PHL	Philadelphia, PA	1008	1302	3.17	5	2	7	9	112	2	727-100
PHX	Phoenix, AZ	801	868	2.23	6	4	4	8	100	1	F100
PIT	Pittsburgh, PA	426	1067	2.8	3	3		3	142		S80
PDX	Portland, OR	568	1616	3.83	4	2	2	4	142	1	S80
RDU	Raleigh, NC	1197	1061	2.78	7	2	8	10	120	2	727-100
PVRGDL	Puerto Vallarta, Guadalajara	418		1.5	1	5		5	84		F100

Table 2 (cont.)

City served		Trad seats	Miles to city	Block Time	Trad dep	Basic dep	CH Extra	CH total	Seats/ dep	Added planes	Plane provided
RNO	Reno NV	496	1345	3.03	4	2	2	4	124	1	727-100
RICSDF	Richmond, VA	410	1157	2.73	1	3		3	137		S80
STL	St. Louis, MO	860		1.87	6	3	5	8	108	1	727-100
SJC	San Jose, CA	1001	1439	3.52	6	2	6	8	125	2	727-100
SJU	San Juan, Peurto Rico	487	2164	3.82	2	2		2	244		MD11
SAT	San Antonio, TX	2033	246	1.03	11	6	9	15	136	1	S80
SEA	Seattle, WA	867	1660	3.92	6	2	5	7	124	2	727-100
SAN	San Diego CA	967	1171	2.72	6	3	3	6	161	1	767-200
SHVBTR	Shrevport LA, Baton Rouge	697		3.2		3		3	232		MD11
SFO	San Francisco CA	1048	1465	3.62	7	2	8	10	105	3	F100
TPA	Tampa, FL	750	928	2.32	5	3	4	7	107	1	F100
DTW	Detroit, MI	710	986	2.6	5	2	3	5	142	1	S80
LGA	New York, NY	3117	1395	3.42	17	2	14	16	195	8	757
ORF	Norfolk, VA	426	1212	2.83	3	3		3	142		S80
TUL	Tulsa, OK	1656	237	1.05	11	6	8	14	118	1	727-100
DCA	Washington D.C.	2312	1185	2.8	14	3	12	15	154	4	727-100
NRT	Tokyo, Japan	241	6430	12.08	1	1		1	241		MD11
YYZ	Toronto Canada	496	1199	2.93	3	3		3	165		767-200
TUS	Tuscon, AZ.	710	814	2.15	5	3	4	7	101	1	F100
PBI	West Palm Beach, FL	284	1102	2.7	2	2		2	142		S80
ICT	Wichita, KS	750	329	1.15	5	5		5	150		727-200
SLC	Salt Lake City, UT	568	988	2.5	4	2	3	5	114	1	727-100

Table 3

Aircraft used in the Continuous Hub Scenario

Aircraft	Seats Available	Aircraft to compliment CHub Schedule	Operating costs/ block hour	Cost/Seat Block hour
McDonnell Douglas DC10	291	2	3397	11.67
Airbus A300	267	1	3368	12.61
Mcdonnell Douglas MD11	241	7	-	-
Boeing 767-300	215	2	2577	11.98
Boeing 767-100	196	18	-	-
Boeing 767-200	169	10	2527	14.95
Boeing 727-200	150	14	1728	11.52
Mcdonnell Douglas S80	142	39	1450	10.21
Boeing 727-100	118	35	-	-
Fokker 100	97	21	-	-
Total		149		

- indicates data not available

Note: Operating costs/block hour include Maintenance, Crew and Fuel expenses.

Source: Datagrams from Aviation Week and Space Technology.

11. TRAFFIC DISTRIBUTION RESULTS

Table 4 displays American's arrivals and departures for each scenario for ten-minute intervals. Figure 5 displays the results on a graph. As expected, the traffic is distributed more evenly under the continuous hub scenario than under the traditional scenario.

Table 5 shows Dallas-Fort Worth's arrivals and departures for each scenario over a ten-minute interval. Figure 6 displays these results on a graph. The traffic is again distributed more evenly under the continuous scenario than under the traditional scenario. Table 4 indicates the traditional schedule for American Airlines exceeds IFR capacity during 10 time intervals. Table 5 showing the schedule for all airlines indicates IFR capacity is exceeded 26 times a day and VFR capacity is equaled four times and exceeded once. Under the continuous schedule, American Airlines does not exceed IFR capacity during the day. The airport under the continuous schedule exceeds IFR capacity during 25 time intervals but does not exceed VFR operations.

The IFR violations could probably be reduced by manipulating aircraft turn times, and the initial start time to shift the demand pattern.

Under the traditional hub concept there were an average 28.57 flights during the time periods exceeding IFR capacity. The continuous concept reduces the average to 24.52. Thus, while the number of violations is not reduced,

the magnitude of the violation is greatly reduced. This is very important as delays occurring during inclement weather will be significantly reduced and the negative effect should discipate more rapidly. The continuous concept brings capacity violations under control in VFR conditions and reduces it during IFR operations. The peaks and valleys of the traditional concept are decreased in the continuous scenario, and practical capacity is increased. Figures 5 and 6 have a more uniform distribution of flights than under the traditional hub concept. The shift in the schedule reduces the peaks and delays.

American's continuous schedule flows more uniformly, even though there is a 32 percent increase in the number of flights. This increase serves the spoke cities on a more frequent basis, providing better service, and more connection opportunities.

Table 4

Arrivals and Departures for American Airlines

	Trad	Cont		Trad	Cont		Trad	Cont
510	0	6	1200	19	10	1850	13	10
520	0	7	1210	$\boxed{22}$	9	1900	18	14
530	1	6	1220	3	9	1910	$\boxed{28}$	7
540	2	0	1230	0	11	1920	10	12
550	6	6	1240	0	7	1930	0	7
600	6	3	1250	$\boxed{21}$	9	1940	0	4
610	0	0	1300	$\boxed{21}$	9	1950	0	7
620	0	10	1310	4	6	2000	19	8
630	0	5	1320	0	11	2010	$\boxed{33}$	8
640	3	2	1330	0	5	2020	11	12
650	7	6	1340	1	11	2030	2	5
700	18	4	1350	0	9	2040	18	10
710	7	5	1400	0	11	2050	12	7
720	16	4	1410	0	9	2100	12	7
730	14	4	1420	0	9	2110	11	14
740	4	9	1430	0	5	2120	1	6
750	0	2	1440	1	8	2130	0	7
800	1	9	1450	4	9	2140	1	5
810	15	6	1500	0	9	2150	6	9
820	$\boxed{24}$	10	1510	1	10	2200	$\boxed{29}$	5
830	17	9	1520	1	7	2210	5	10
840	$\boxed{25}$	10	1530	0	5	2220	6	4
850	10	9	1540	0	9	2230	9	11
900	0	10	1550	0	7	2240	4	5
910	0	11	1600	3	12	2250	1	6
920	7	10	1610	3	9	2300	0	8
930	$\boxed{25}$	10	1620	6	15	2310	1	5
940	16	9	1630	0	10	2320	11	7
950	15	11	1640	0	14	2330	0	5
1000	14	12	1650	0	10	2340	1	5
1010	20	7	1700	0	8	2350	0	6
1020	10	11	1710	0	10	0	0	4
1030	0	7	1720	2	10	10	0	2
1040	0	13	1730	5	12	20	0	3
1050	4	11	1740	2	14	30	0	3
1100	$\boxed{27}$	14	1750	1	16	40	0	3
1110	16	12	1800	0	9	50	0	4
1120	12	16	1810	0	10	100	0	2
1130	3	16	1820	0	8	111	1	4
1140	8	12	1830	1	10	123	0	5
1150	10	14	1840	1	7	Total	748	992

Note: The square indicates IFR Capacity exceeded.

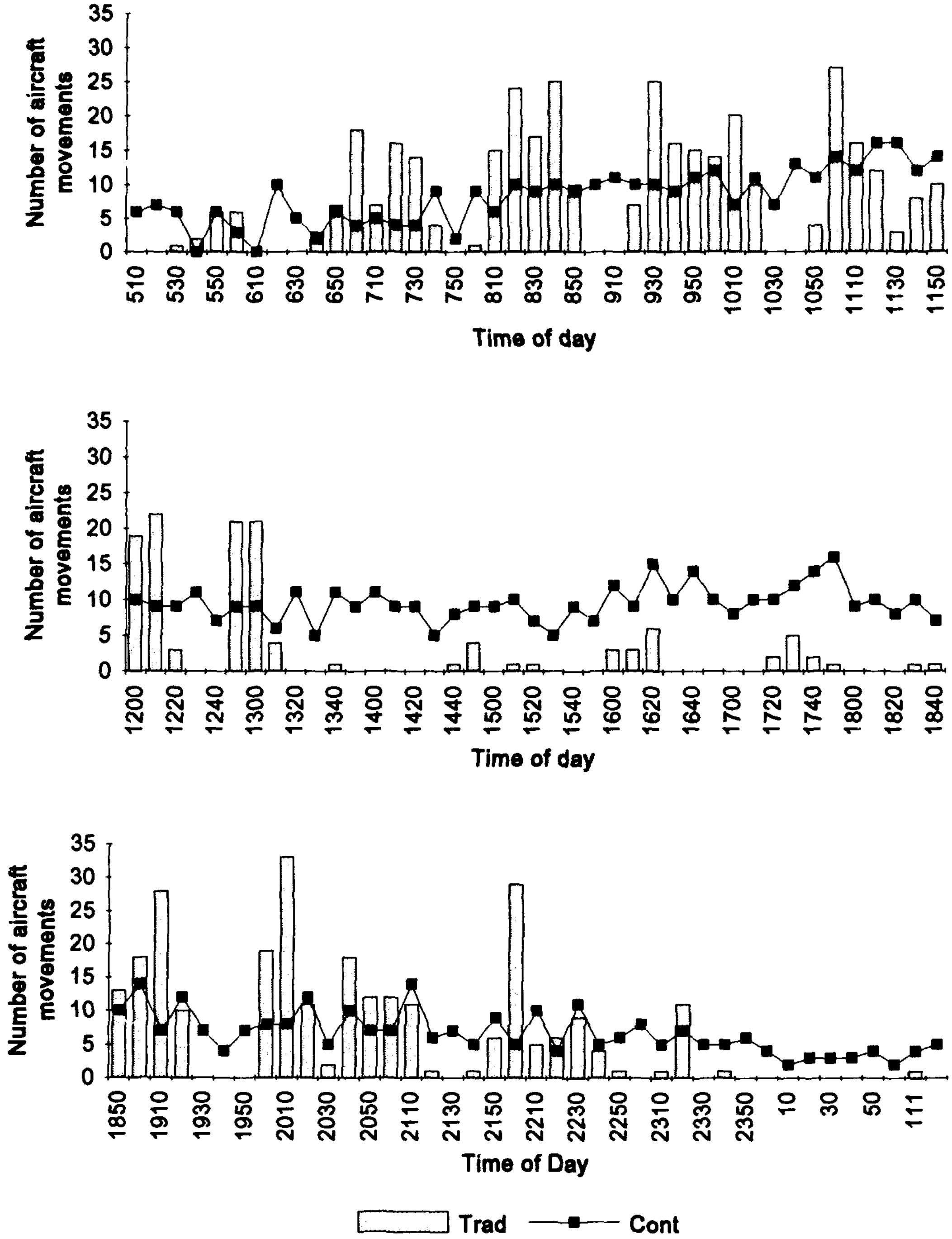

Figure 5
American's Traffic Distribution Comparison

Table 5

Arrivals and Departures of all airlines for DFW

	Trad	Cont		Trad	Cont		Trad	Cont
510	1	7	1200	$\boxed{35}$	$\boxed{26}$	1850	$\boxed{35}$	$\boxed{32}$
520	0	7	1210	$\boxed{33}$	20	1900	$\boxed{27}$	$\boxed{23}$
530	6	11	1220	16	$\boxed{22}$	1910	$\boxed{39}$	18
540	2	0	1230	16	$\boxed{27}$	1920	13	15
550	7	7	1240	1	8	1930	6	13
600	6	3	1250	$\boxed{22}$	10	1940	13	17
610	3	3	1300	$\boxed{29}$	17	1950	6	13
620	10	20	1310	17	19	2000	$\boxed{22}$	11
630	5	10	1320	17	$\boxed{28}$	2010	$\boxed{34}$	9
640	7	6	1330	8	13	2020	13	14
650	9	8	1340	2	12	2030	$\boxed{21}$	$\boxed{24}$
700	19	5	1350	3	12	2040	$\boxed{35}$	$\boxed{27}$
710	8	7	1400	4	15	2050	16	11
720	$\boxed{22}$	10	1410	5	14	2100	12	7
730	$\boxed{24}$	14	1420	12	$\boxed{21}$	2110	13	16
740	13	18	1430	9	14	2120	5	10
750	3	5	1440	4	11	2130	6	13
800	5	13	1450	7	12	2140	12	16
810	$\boxed{29}$	20	1500	6	15	2150	17	20
820	$\boxed{34}$	20	1510	12	$\boxed{21}$	2200	$\boxed{31}$	7
830	$\boxed{24}$	16	1520	14	20	2210	6	11
840	$\boxed{26}$	11	1530	7	12	2220	10	8
850	10	9	1540	4	13	2230	$\boxed{22}$	$\boxed{24}$
900	10	20	1550	4	11	2240	11	12
910	6	17	1600	11	20	2250	1	6
920	9	12	1610	12	18	2300	0	8
930	$\boxed{26}$	11	1620	18	$\boxed{27}$	2310	1	5
940	$\boxed{24}$	17	1630	6	16	2320	12	8
950	$\boxed{32}$	$\boxed{28}$	1640	3	17	2330	2	7
1000	$\boxed{24}$	$\boxed{22}$	1650	15	$\boxed{25}$	2340	2	6
1010	20	7	1700	15	$\boxed{23}$	2350	0	6
1020	15	16	1710	9	19	0	0	4
1030	6	13	1720	6	14	10	0	2
1040	8	$\boxed{21}$	1730	5	12	20	0	3
1050	10	17	1740	11	$\boxed{23}$	30	0	3
1100	$\boxed{35}$	$\boxed{22}$	1750	7	$\boxed{22}$	40	0	3
1110	$\boxed{32}$	$\boxed{28}$	1800	12	$\boxed{21}$	50	0	4
1120	19	$\boxed{23}$	1810	13	$\boxed{23}$	100	0	2
1130	6	19	1820	8	16	111	1	4
1140	10	14	1830	2	11	123	0	5
1150	$\boxed{26}$	$\boxed{30}$	1840	3	9			

Note: The square indicates IFR Capacity exceeded.

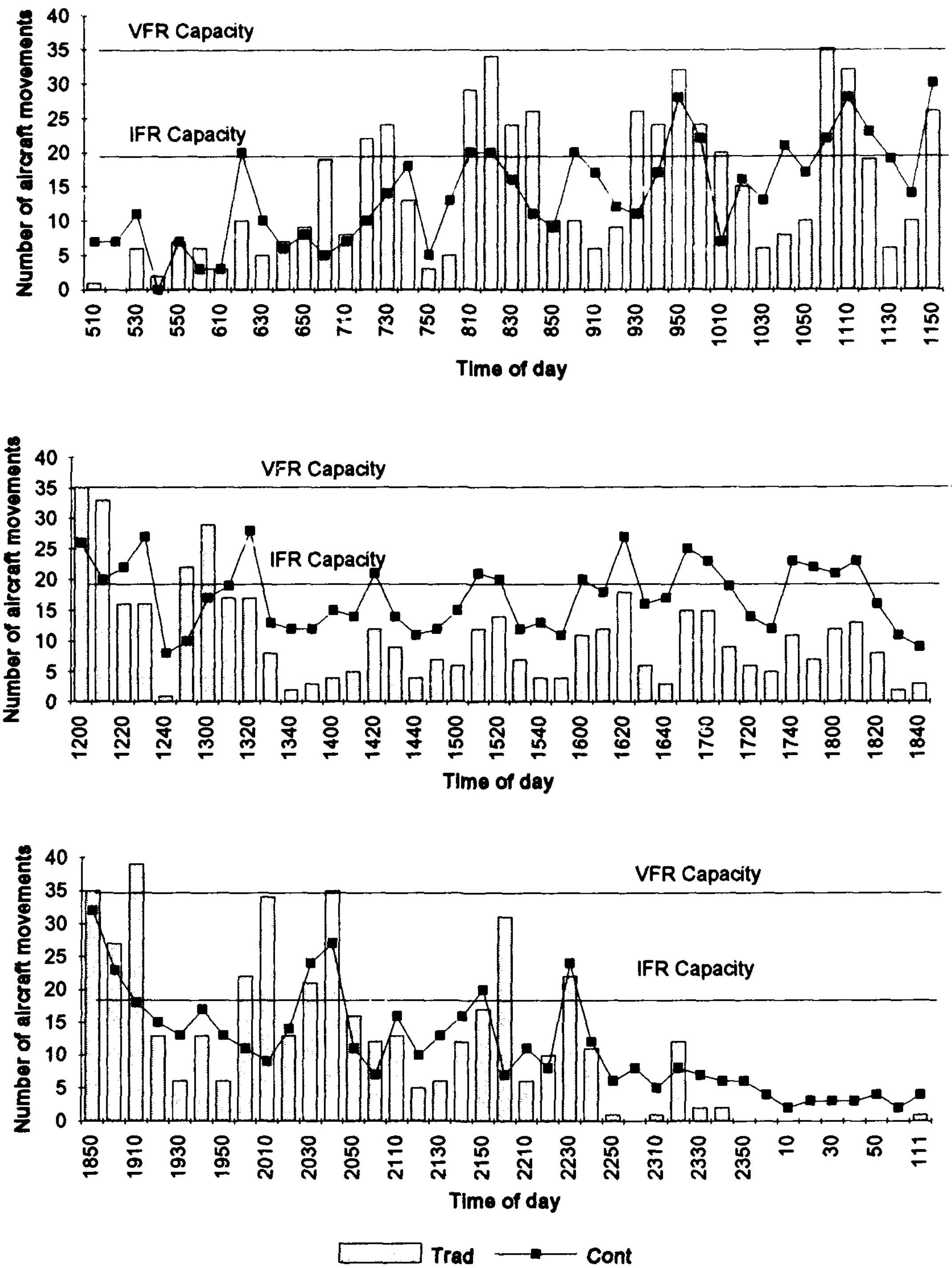

Figure 6
Dallas-Fort Worth Traffic Distribution

12. FLEET OPERATIONAL COSTS

Additional flying is involved under the continuous scenario. Table 4 indicates the continuous schedule requires 992 arrivals and departures compared to 748 arrivals and departures for the traditional schedule. It is essential that these extra sorties are accomplished at minimum costs. This points to the need to reduce system operating costs per block hour, which dictates using smaller aircraft. By using smaller aircraft flying with greater frequency, the available seats to each destination remain unchanged. However, greater flight frequency generates an opportunity to increase revenue by providing more convenient service.

The fleet operation costs need to be reviewed. Table 3 displayed the operational costs per block hour for each aircraft in American's fleet. American Airlines will require a fleet mix focused predominantly towards smaller aircraft such as the Fokker 100 and the McDonnell Douglas MD 80.

A 32 percent increase in flight segments were required with the continuous scenario. The operational costs will decrease because the need to operate the high capacity aircraft is reduced. The cost of an A300 wide body aircraft per block hour of operation per passenger is $12.61 where an S80 is $10.21 (Table 3).

The continuous concept requires 149 aircraft. (Table 3) American currently has a compliment of 216 aircraft dedicated to Dallas-Fort Worth (AMR 1992). A significant reduction in the number of aircraft can be accomplished under the continuous concept. However, the exact number can not be defined in this paper since airline policy would dictate the number of spare planes required for reliable service. Naturally high ownership costs are greatly reduced by decreasing both the size and the number of aircraft.

13. GATE COMPARISON

By analyzing the aircraft departures under the continuous schedule based on 1 hour time intervals, the gate area needed for operations were found. Table 6 shows the results for each time interval. A maximum of 46 ticket counters are needed to accommodate the continuous schedule. Table 7 shows the actual gates needed for aircraft are 17. American currently owns 54 gates at Dallas Fort Worth. A reduction in manpower requirements can be attained. The need to staff 54 gates can be reduced to staffing 46 ticket counters for 17 gates. Staffing is now accomplished for a much lower peak gate operation.

Table 6

Projected Ticket Counters

Time	Gates	Time	Gates	Time	Gates
0 - 1	28	6.8347 - 7.8347	27	13.8361 - 14.8361	27
0.1667 - 1.1667	22	7.0014 - 8.0014	28	14.0028 - 15.0028	22
0.3334 - 1.3334	23	7.1681 - 8.1681	27	14.1695 - 15.1695	19
0.5001 - 1.5001	19	7.3348 - 8.3348	26	14.3362 - 15.3362	19
0.6668 - 1.6668	21	7.5015 - 8.5015	24	14.5029 - 15.5029	22
0.8335 - 1.8335	19	7.6682 - 8.6682	27	14.6696 - 15.6696	23
1.0002 - 2.0002	20	7.8349 - 8.8349	23	14.8363 - 15.8363	18
1.1669 - 2.1669	22	8.0016 - 9.0016	24	15.003 - 16.003	22
1.3336 - 2.3336	14	8.1683 - 9.1683	28	15.1697 - 16.1697	26
1.5003 - 2.5003	15	8.335 - 9.335	29	15.3364 - 16.3364	20
1.667 - 2.667	17	8.5017 - 9.5017	28	15.5031 - 16.5031	18
1.8337 - 2.8337	14	8.6684 - 9.6684	25	15.6698 - 16.66[illegible]8	17
2.0004 - 3.0004	15	8.8351 - 9.8351	26	15.8365 - 16.8[illegible]5	20
2.1671 - 3.1671	14	9.0018 - 10.002	26	16.0032 - 17.0032	16
2.3338 - 3.3338	19	9.1685 - 10.169	25	16.1699 - 17.1699	13
2.5005 - 3.5005	21	9.3352 - 10.335	23	16.3366 - 17.3366	13
2.6672 - 3.6672	22	9.5019 - 10.502	25	16.5033 - 17.5033	15
2.8339 - 3.8339	25	9.6686 - 10.669	25	16.67 - 17.67	13
3.0006 - 4.0006	25	9.8353 - 10.835	24	16.8367 - 17.8367	15
3.1673 - 4.1673	29	10.002 - 11.002	24	17.0034 - 18.0034	17
3.334 - 4.334	29	10.1687 - 11.169	23	17.1701 - 18.1701	15
3.5007 - 4.5007	30	10.3354 - 11.335	26	17.3368 - 18.3368	17
3.6674 - 4.6674	30	10.5021 - 11.502	26	17.5035 - 18.5035	13
3.8341 - 4.8341	30	10.6688 - 11.669	31	17.6702 - 18.6702	12
4.0008 - 5.0008	32	10.8355 - 11.836	35	17.8369 - 18.8369	8
4.1675 - 5.1675	31	11.0022 - 12.002	36	18.0036 - 19.0036	10
4.3342 - 5.3342	31	11.1689 - 12.169	35	18.1703 - 19.1703	11
4.5009 - 5.5009	28	11.3356 - 12.336	30	18.337 - 19.337	11
4.6676 - 5.6676	29	11.5023 - 12.502	32	18.5037 - 19.5037	13
4.8343 - 5.8343	29	11.669 - 12.669	32	18.6704 - 19.6704	16
5.001 - 6.001	29	11.8357 - 12.836	32	18.8371 - 19.8371	19
5.1677 - 6.1677	32	12.0024 - 13.002	32	19.0038 - 20.0038	17
5.3344 - 6.3344	34	12.1691 - 13.169	35	19.1705 - 20.1705	17
5.5011 - 6.5011	36	12.3358 - 13.336	39	19.3372 - 20.3372	16
5.6678 - 6.6678	39	12.5025 - 13.503	36	19.5039 - 20.5039	14
5.8345 - 6.8345	$\boxed{46}$	12.6692 - 13.669	30	19.6706 - 20.6706	15
6.0012 - 7.0012	42	12.8359 - 13.836	31	19.8373 - 20.8373	11
6.1679 - 7.1679	39	13.0026 - 14.003	30	20.004 - 21.004	9
6.3346 - 7.3346	38	13.1693 - 14.169	28	20.1707 - 21.1707	7
6.5013 - 7.5013	38	13.336 - 14.336	29	20.3374 - 21.3374	5
6.668 - 7.668	32	13.5027 - 14.503	28	20.5041 - 21.5041	4
		13.6694 - 14.669	29		

Table 7

Projected Gates

Time		Gates	Time		Gates
0 -	0.333	13	10.323 -	10.656	6
0.333 -	0.666	5	10.656 -	10.989	7
0.666 -	0.999	6	10.989 -	11.322	12
0.999 -	1.332	11	11.322 -	11.655	9
1.332 -	1.665	3	11.655 -	11.988	13
1.665 -	1.998	5	11.988 -	12.321	8
1.998 -	2.331	6	12.321 -	12.654	12
2.331 -	2.664	5	12.654 -	12.987	14
2.664 -	2.997	8	12.987 -	13.32	13
2.997 -	3.33	5	13.32 -	13.653	5
3.33 -	3.663	10	13.653 -	13.986	12
3.663 -	3.996	3	13.986 -	14.319	12
3.996 -	4.329	$\boxed{17}$	14.319 -	14.652	6
4.329 -	4.662	11	14.652 -	14.985	7
4.662 -	4.995	11	14.985 -	15.318	9
4.995 -	5.328	9	15.318 -	15.651	11
5.328 -	5.661	6	15.651 -	15.984	5
5.661 -	5.994	12	15.984 -	16.317	12
5.994 -	6.327	13	16.317 -	16.65	13
6.327 -	6.66	15	16.65 -	16.983	6
6.66 -	6.993	14	16.983 -	17.316	9
6.993 -	7.326	10	17.316 -	17.649	12
7.326 -	7.659	7	17.649 -	17.982	9
7.659 -	7.992	11	17.982 -	18.315	5
7.992 -	8.325	8	18.315 -	18.648	9
8.325 -	8.658	8	18.648 -	18.981	11
8.658 -	8.991	6	18.981 -	19.314	6
8.991 -	9.324	15	19.314 -	19.647	8
9.324 -	9.657	4	19.647 -	19.98	5
9.657 -	9.99	9	19.98 -	20.313	11
9.99 -	10.32	10	20.313 -	20.646	5

14. RECOMMENDATIONS FOR MORE RESEARCH

Cost Analysis

A complete cost analysis would include the block operating costs for each type of aircraft multiplied by its daily utilization under the traditional schedule. A comparative figure would then be found under the continuous schedule and the overall operating costs could then be found and analyzed. The block operating costs would include fixed costs (eg, aircraft leases/ownership costs, hangars, gates etc) along with the variable costs (fuel, manpower, maintenance, etc). This analysis requires a level of sophistication beyond what could be accomplished in this research.

Schedule Efficiency

Schedule efficiency could be realized with minor changes in the schedule to distribute the peak periods more evenly than currently exists in the schedule, resulting in fewer gates required and less IFR capacity violations.

Hyper Hub Analysis

An airport hub could realize greater efficiency with all airlines stationed there implementing a continuous hub scheduling scheme. A parallel analysis could be accomplished much the same as the airline analysis, which was portrayed in this research.

15. CONCLUSION

This research evaluated the continuous hub concept as a means of improving the efficient use of airport capacity. The continuous concept shifts the demand pattern to a more uniform distribution. According to Robert Horonjeff, the more uniform the distribution the lower the delay. Therefore, the delay can be reduced without increasing the ultimate capacity of an airport reducing the need for expensive new ground facilities.

Several immediate conclusions can be drawn from this analysis.

a) The daily fleet is better utilized under the continuous operation with 67 less aircraft providing a 32% increase in flight operations.

b) Aircraft needs are predominantly smaller. The need for wide-body aircraft are reduced and replaced by frequency of operations.

c) The gate facilities required under the continuous scenario are reduced from 54 to 46. This provides capacity for expansion of operations and passenger flow at Dallas-Fort Worth, without adding extra facilities.

d) Staffing requirements and related expenses drop. Fewer gates require fewer ramp crews, push crews, and gate agents.

e) Runway and taxiway waits can be reduced. The continuous concept requires a maximum launching of 32

aircraft during peak periods compared to 39 under the traditional hub scenario.

The hub-spoke system was a giant step in system efficiency over the prior regulated system of point-to-point routes. However, it is not totally efficient and should be at least partially modified to allow larger carriers to effectively compete.

Passenger flows are increasing. Concurrently, airline bankruptcies are reducing the number of carriers, focusing passenger flows for connecting flights into fewer hubs. Thus, the passenger flows at these hubs are increasing at an accelerated rate. This provides sufficient demand to justify the continuous hub concept.

Continuous hub operations would mean a new airport capacity outlook. Flow of traffic would change without the specifically-timed connecting complexes. This would result in fewer gates and less peak-period demands put on the runways.

The focus of the analysis is on the benefits to American Airlines in implementing a continuous hub schedule at Dallas-Fort Worth. Southwest Airlines is operating profitably under a version of the concept, but American Airlines differs with a wider more traditional product: dual-class cabins, advance and through seat assignments, interline ticketing and baggage, etc. Each increases turn aircraft times.

The cost of doing business at existing hubs in traditional ways means more gates, larger aircraft, and more runways, none of which come easily or cheaply. Carriers must move to make some changes in the way they schedule flights and serve passengers. The successful application of this concept by Southwest Airlines demonstrates it viability. This research demonstrates the continuous concept is also a viable alternative for American Airlines operations at Dallas-Fort Worth.

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APPENDIX A

SCHEDULE PRODUCTION

Appendix A explains how Appendix B was formed and how the schedule was produced. The original schedule was designed giving the longer stage lengths priority in take off times. The longest stage length was the first to depart and the second longest stage length was the second to depart, etc. Therefore Tokyo (NRT) departed first because its stage length was 12.08 hours followed by Madrid with a stage length of 9.67 hours. Once the initial departure to a city was assigned, the remaining schedule for that city was determined from block and turn times.

For the continuous hub schedule to be as efficient as possible, modification had to be made. This original schedule procedure resulted in many early morning departures which would not be desirable to the airline. Therefore, the first departure was canceled for several flights as identified by the "d" in Appendix B. The early morning departures remaining were to accommodate long haul flights such as Tokyo and Madrid.

The flights that could not be deleted were delayed to a later start time as depicted in Appendix B with a (+.5, +1, +2, +3), these indicate a 30 minute addition, 1 hour addition, 2 hour addition, and a 3 hour addition, respectively. When these codes are shown no departure occurred at this time.

Appendix B designates departures with a code. Each code is explained below:

X- Designates the departure of an extra aircraft stationed at the spoke city and is also running a continuous cycle.

O- Designates the first departure of the X aircraft from Dallas Fort Worth.

XY- Designates a departure of a second or third aircraft added to the route stationed at Dallas Fort Worth.

A number under in the code column identifies the number of departures to that city. (eg. A 2 indicates the second departure to that city by the primary aircraft.)

+.5,+1,+2,+3 indicates the departure delayed by this time.

d- indicates the flight was cancelled.

APPENDIX B

CONTINUOUS HUB SCHEDULE

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
		0	+.5	NRT
		0		MAD
		0		ORY
		0	+2	HNL
		0	+2	SEA
		0	+2	PDX
		0		SJU
		0	d	YYC
		0		SFO
		0	d	BOS
		0		SJC
		0	d	LGA
		0		OAK
		0	d	BDL
		0.25	+3	SMF
		0.25		SHV-BTR-MOB
		0.25	d	PHL
		0.25		FAT
		0.25		RIC-SDF
		0.25	d	BFL
		0.25	d	RNO
		0.25		BUR
		0.25	d	BWI
		0.25		LGB
		0.25	d	SNA
		0.25		YYZ
		0.25		LAX
		0.25	+1	ORF
		0.5	d	FLL
		0.5		PIT
		0.5		NRT
		0.5	d	DCA
		0.5	d	RDU
		0.5	d	ONT
		0.5		MIA
		0.5		SAN
		0.5	d	PBI
		0.5		LIT-JAN
		0.5	d	CLE
		0.5	d	DTW
		0.5		LAS

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
		0.5	d	MCO
		0.75	d	RSW
		0.75	d	SLC
		0.75		GSO
		0.75	d	CLT
		0.75		MFE-MTY
		0.75		CMH
		0.75	d	MEX
		0.75		MSP
		0.75	d	TPA
		0.75	d	JAX
		0.75		ORD
		0.75	d	DAY
		0.75		PHX
		0.75	d	TUS
		1	d	IND
		1	d	CVG
		1	d	ATL
		1		JAC-LBB
		1	d	DEN
		1	d	DSM
		1	d	STL
		1	d	COS
		1		OMA
		1		HSV
		1	d	ABQ
		1	d	BNA
		1	d	BHM
		1	d	CUN
		1	d	MCI
		1.25		ORF
		1.25		MSY
		1.25		PVR-GDL
		1.25	d	ELP
		1.25	d	MEM
		1.25		HRL
		1.25		MAF
		1.25		CRP
		1.25		AMA
		1.25	d	ICT
		1.25	d	TUL
		1.25	d	SAT
		1.25	d	HOU

Airport (FROM)	Arrival Time	Dprt Time		Airport (TO)
		1.25	d	OKC
		1.25		AUS
		1.5	XY	LGA
		1.5	XY	DCA
OKC	1.263	1.596	O	OKC
HOU	1.333	1.666	O	HOU
SAT	1.363	1.696	O	SAT
TUL	1.383	1.716	O	TUL
		1.75	XY	LGA
ORD	1.5	1.833	XY	ORD
		2	XY	LGA
		2		HNL
		2		SEA
		2		PDX
LIT	1.673	2.006	O	LIT
MCI	1.833	2.166	O	MCI
CLE	2.003	2.336	O	CLE
BNA	2.013	2.346	O	BNA
ABQ	2.033	2.366	O	ABQ
STL	2.203	2.536	O	STL
DEN	2.253	2.586	O	DEN
ATL	2.333	2.666	O	ATL
HOU	2.333	2.666	O	HOU
TUS	2.483	2.816	O	TUS
PHX	2.563	2.896	O	PHX
ORD	2.583	2.916	O	ORD
MEX	2.653	2.986	O	MEX
MSP	2.653	2.986	O	MSP
TPA	2.653	2.986	O	TPA
CLT	2.753	3.086	O	CLT
MCO	2.863	3.196	O	MCO
LAS	2.883	3.216	O	LAS
SLC	2.883	3.216	O	SLC
DTW	2.933	3.266	O	DTW
SAN	3.053	3.386	O	SAN
MIA	3.063	3.396	O	MIA
ONT	3.083	3.416	O	ONT
RDU	3.113	3.446	O	RDU
DCA	3.133	3.466	O	DCA
AUS	3.24	3.573	2	AUS
DEN	3.253	3.586	O	DEN
LAX	3.253	3.586	O	LAX

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
SNA	3.263	3.596	O	SNA
BWI	3.303	3.636	O	BWI
OKC	3.36	3.693	1	OKC
RNO	3.363	3.696	O	RNO
OKC	3.373	3.706	X	OKC
HOU	3.5	3.833	1	HOU
PHL	3.503	3.836	O	PHL
SAT	3.56	3.893	1	SAT
HOU	3.583	3.916	X	HOU
ORD	3.583	3.916	O	ORD
TUL	3.6	3.933	1	TUL
SAT	3.673	4.006	X	SAT
BDL	3.683	4.016	O	BDL
TUL	3.733	4.066	X	TUL
LGA	3.753	4.086	O	LGA
ICT	3.8	4.133	1	ICT
AMA	3.84	4.173	2	AMA
SJC	3.853	4.186	O	SJC
BOS	3.883	4.216	O	BOS
CRP	3.9	4.233	2	CRP
SFO	3.953	4.286	O	SFO
YYC	4.063	4.396	O	YYC
MIA	4.063	4.396	O	MIA
RDU	4.113	4.446	O	RDU
DCA	4.133	4.466	O	DCA
MAF	4.16	4.493	2	MAF
PDX	4.163	4.496	O	PDX
HRL	4.18	4.513	1	HRL
MCI	4.25	4.583	1	MCI
LAX	4.253	4.586	O	LAX
SEA	4.253	4.586	O	SEA
MEM	4.26	4.593	1	MEM
ELP	4.44	4.773	1	ELP
CUN	4.49	4.823	1	CUN
MSY	4.5	4.833	2	MSY
PVR-GDL	4.5	4.833	2	PVR-GDL
PHL	4.503	4.836	O	PHL
BHM	4.55	4.883	1	BHM
HOU	4.583	4.916	X	HOU
ORD	4.583	4.916	O	ORD
LIT	4.603	4.936	X	LIT
BNA	4.61	4.943	1	BNA
ABQ	4.65	4.983	1	ABQ

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
HSV	4.71	5.043	2	HSV
COS	4.75	5.083	1	COS
OMA	4.75	5.083	2	OMA
LGA	4.753	5.086	O	LGA
SJC	4.853	5.186	O	SJC
BOS	4.883	5.216	O	BOS
SFO	4.953	5.286	O	SFO
DSM	4.99	5.323	1	DSM
STL	4.99	5.323	1	STL
MCI	5.083	5.416	X	MCI
DEN	5.09	5.423	1	DEN
DCA	5.133	5.466	O	DCA
ATL	5.25	5.583	1	ATL
JAC-LBB	5.25	5.583	2	JAC-LBB
LAX	5.253	5.586	O	LAX
SEA	5.253	5.586	O	SEA
IND	5.26	5.593	1	IND
TUS	5.3	5.633	1	TUS
PHX	5.46	5.793	2	PHX
CVG	5.49	5.823	1	CVG
ORD	5.5	5.833	2	ORD
DAY	5.5	5.833	1	DAY
JAX	5.56	5.893	1	JAX
AUS	5.563	5.896	3	AUS
CLE	5.593	5.926	X	CLE
BNA	5.623	5.956	X	BNA
MEX	5.64	5.973	1	MEX
MSP	5.64	5.973	2	MSP
TPA	5.64	5.973	1	TPA
ABQ	5.683	6.016	X	ABQ
CMH	5.7	6.033	2	CMH
RSW	5.75	6.083	1	RSW
LGA	5.753	6.086	O	LGA
OKC	5.803	6.136	2	OKC
MCO	5.81	6.143	1	MCO
OKC	5.816	6.149	X	OKC
CLT	5.84	6.173	1	CLT
MFE-MTY	5.84	6.173	2	MFE-MTY
LAS	5.85	6.183	2	LAS
GSO	5.86	6.193	2	GSO
DTW	5.95	6.283	1	DTW
SFO	5.953	6.286	O	SFO
SLC	6	6.333	1	SLC

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
HOU	6.083	6.416	2	HOU
CLE	6.09	6.423	1	CLE
PBI	6.15	6.483	1	PBI
LIT-JAN	6.15	6.483	2	LIT-JAN
HOU	6.166	6.499	X	HOU
SAN	6.19	6.523	2	SAN
STL	6.193	6.526	X	STL
SAT	6.203	6.536	2	SAT
MIA	6.21	6.543	2	MIA
ONT	6.25	6.583	1	ONT
ORD	6.25	6.583	XY	ORD
TUL	6.283	6.616	2	TUL
RDU	6.31	6.643	1	RDU
SAT	6.316	6.649	X	SAT
LAX	6.34	6.673	2	LAX
DEN	6.343	6.676	X	DEN
PIT	6.35	6.683	2	PIT
DCA	6.35	6.683	1	DCA
SNA	6.36	6.693	1	SNA
YYZ	6.36	6.693	2	YYZ
FLL	6.39	6.723	1	FLL
LGB	6.4	6.733	2	LGB
TUL	6.416	6.749	X	TUL
BWI	6.44	6.773	1	BWI
BUR	6.5	6.833	2	BUR
RNO	6.56	6.893	1	RNO
ATL	6.583	6.916	X	ATL
BFL	6.64	6.973	1	BFL
ICT	6.683	7.016	2	ICT
RIC-SDF	6.7	7.033	2	RIC-SDF
LGA	6.753	7.086	O	LGA
AMA	6.763	7.096	3	AMA
PHL	6.84	7.173	1	PHL
FAT	6.84	7.173	2	FAT
CRP	6.883	7.216	3	CRP
SHV-BTR-MOB	6.9	7.233	2	SHV-BTR-MOB
BDL	6.95	7.283	1	BDL
OAK	6.99	7.323	2	OAK
TUS	7.033	7.366	X	TUS
LGA	7.09	7.423	1	LGA
ORF	7.16	7.493	2	ORF
HNL	7.163	7.496	O	HNL
HOU	7.166	7.499	X	HOU

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
PHX	7.273	7.606	X	PHX
SJC	7.29	7.623	2	SJC
ORD	7.333	7.666	X	ORD
DEN	7.343	7.676	X	DEN
BOS	7.35	7.683	1	BOS
DCA	7.35	7.683	2	DCA
MAF	7.403	7.736	3	MAF
HRL	7.443	7.776	2	HRL
SFO	7.49	7.823	2	SFO
MEX	7.543	7.876	X	MEX
MSP	7.543	7.876	X	MSP
TPA	7.543	7.876	X	TPA
MEM	7.603	7.936	2	MEM
YYC	7.71	8.043	1	YYC
LGA	7.753	8.086	O	LGA
MCI	7.833	8.166	2	MCI
CLT	7.843	8.176	X	CLT
LIT	7.866	8.199	X	LIT
AUS	7.886	8.219	4	AUS
SJU	7.89	8.223	2	SJU
ELP	7.963	8.296	2	ELP
MSY	8.083	8.416	3	MSY
PVR-GDL	8.083	8.416	3	PVR-GDL
SLC	8.083	8.416	X	SLC
MCO	8.173	8.506	X	MCO
LAS	8.233	8.566	X	LAS
OKC	8.246	8.579	3	OKC
OKC	8.259	8.592	X	OKC
CUN	8.313	8.646	2	CUN
ORD	8.333	8.666	X	ORD
DTW	8.383	8.716	X	DTW
BHM	8.433	8.766	2	BHM
BNA	8.553	8.886	2	BNA
LGA	8.59	8.923	2	LGA
ABQ	8.633	8.966	2	ABQ
HOU	8.666	8.999	3	HOU
MCI	8.666	8.999	X	MCI
SAN	8.743	9.076	X	SAN
HOU	8.749	9.082	X	HOU
HSV	8.753	9.086	3	HSV
MIA	8.773	9.106	X	MIA
COS	8.833	9.166	2	COS
OMA	8.833	9.166	3	OMA

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
ONT	8.833	9.166	X	ONT
LGA	8.84	9.173	2	LGA
SAT	8.846	9.179	3	SAT
RDU	8.923	9.256	X	RDU
SAT	8.959	9.292	X	SAT
TUL	8.966	9.299	3	TUL
DCA	8.983	9.316	X	DCA
LGA	9.09	9.423	2	LGA
TUL	9.099	9.432	X	TUL
DSM	9.313	9.646	2	DSM
STL	9.313	9.646	2	STL
ORD	9.333	9.666	X	ORD
LAX	9.343	9.676	X	LAX
SNA	9.373	9.706	X	SNA
BWI	9.493	9.826	X	BWI
DEN	9.513	9.846	2	DEN
CLE	9.516	9.849	X	CLE
ICT	9.566	9.899	3	ICT
BNA	9.566	9.899	X	BNA
ABQ	9.666	9.999	X	ABQ
RNO	9.673	10.006	X	RNO
AMA	9.686	10.019	4	AMA
HOU	9.749	10.082	X	HOU
MIA	9.773	10.106	X	MIA
ATL	9.833	10.166	2	ATL
JAC-LBB	9.833	10.166	3	JAC-LBB
CRP	9.866	10.199	4	CRP
PDX	9.91	10.243	2	PDX
RDU	9.923	10.256	X	RDU
DCA	9.983	10.316	X	DCA
PHL	10.093	10.426	X	PHL
SEA	10.09	10.426	2	SEA
IND	10.103	10.436	2	IND
SMF	10.16	10.44	2	SMF
TUS	10.183	10.516	2	TUS
AUS	10.209	10.542	5	AUS
CVG	10.313	10.646	2	CVG
LAX	10.343	10.676	X	LAX
PHX	10.503	10.836	3	PHX
STL	10.516	10.849	X	STL
ORD	10.583	10.916	3	ORD
DAY	10.583	10.916	2	DAY
BDL	10.633	10.966	X	BDL

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
MAF	10.646	10.979	4	MAF
OKC	10.689	11.022	4	OKC
OKC	10.702	11.035	X	OKC
JAX	10.703	11.036	2	JAX
HRL	10.706	11.039	3	HRL
DEN	10.766	11.099	X	DEN
LGA	10.843	11.176	X	LGA
MEX	10.863	11.196	2	MEX
MSP	10.863	11.196	3	MSP
TPA	10.863	11.196	2	TPA
MEM	10.946	11.279	3	MEM
DCA	10.983	11.316	X	DCA
CMH	10.983	11.316	3	CMH
PHL	11.093	11.426	X	PHL
LIT	11.129	11.462	X	LIT
SJC	11.143	11.476	X	SJC
ATL	11.166	11.499	X	ATL
BOS	11.233	11.566	X	BOS
HOU	11.249	11.582	4	HOU
CLT	11.263	11.596	2	CLT
MFE-MTY	11.263	11.596	3	MFE-MTY
GSO	11.303	11.636	3	GSO
HOU	11.332	11.665	X	HOU
RSW	11.333	11.666	2	RSW
ORD	11.333	11.666	XY	ORD
LAX	11.343	11.676	X	LAX
MCI	11.416	11.749	3	MCI
SFO	11.443	11.776	X	SFO
MCO	11.453	11.786	2	MCO
ELP	11.486	11.819	3	ELP
SAT	11.489	11.822	4	SAT
LAS	11.533	11.866	3	LAS
SLC	11.583	11.916	2	SLC
SAT	11.602	11.935	X	SAT
TUL	11.649	11.982	4	TUL
MSY	11.666	11.999	4	MSY
PVR-GDL	11.666	11.999	4	PVR-GDL
DTW	11.733	12.066	2	DTW
DEN	11.766	12.099	X	DEN
YYC	11.773	12.106	X	YYC
TUL	11.782	12.115	X	TUL
LGA	11.843	12.176	X	LGA
TUS	11.916	12.249	X	TUS

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
CLE	12.013	12.346	2	CLE
PDX	12.073	12.406	X	PDX
PBI	12.133	12.466	2	PBI
LIT-JAN	12.133	12.466	3	LIT-JAN
CUN	12.136	12.469	3	CUN
SJC	12.143	12.476	X	SJC
SAN	12.213	12.546	3	SAN
BOS	12.233	12.566	X	BOS
MCI	12.249	12.582	X	MCI
MIA	12.253	12.586	3	MIA
BHM	12.316	12.649	3	BHM
PHX	12.316	12.649	X	PHX
HOU	12.332	12.665	X	HOU
ONT	12.333	12.666	2	ONT
SEA	12.343	12.676	X	SEA
ORD	12.416	12.749	X	ORD
SFO	12.443	12.776	X	SFO
ICT	12.449	12.782	4	ICT
RDU	12.453	12.786	2	RDU
BNA	12.496	12.829	3	BNA
AUS	12.532	12.865	6	AUS
PIT	12.533	12.866	3	PIT
DCA	12.533	12.866	2	DCA
AMA	12.609	12.942	5	AMA
FLL	12.613	12.946	2	FLL
ABQ	12.616	12.949	3	ABQ
LAX	12.763	13.096	3	LAX
MEX	12.766	13.093	X	MEX
MSP	12.766	13.099	X	MSP
TPA	12.766	13.099	X	TPA
HSV	12.796	13.129	4	HSV
SNA	12.803	13.136	2	SNA
YYZ	12.803	13.136	3	YYZ
LGA	12.843	13.176	X	LGA
CRP	12.849	13.182	5	CRP
LGB	12.883	13.216	3	LGB
COS	12.916	13.249	3	COS
OMA	12.916	13.249	4	OMA
BWI	12.963	13.296	2	BWI
BUR	13.083	13.416	3	BUR
OKC	13.132	13.465	5	OKC
OKC	13.145	13.478	X	OKC
RNO	13.203	13.536	2	RNO

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
CLT	13.266	13.599	X	CLT
SEA	13.343	13.676	X	SEA
BFL	13.363	13.696	2	BFL
ORD	13.416	13.749	X	ORD
CLE	13.439	13.772	X	CLE
ORF	13.4	13.776	3	ORF
SFO	13.443	13.776	X	SFO
RIC-SDF	13.483	13.816	3	RIC-SDF
BNA	13.509	13.842	X	BNA
DCA	13.533	13.866	3	DCA
DSM	13.636	13.969	3	DSM
STL	13.636	13.969	3	STL
ABQ	13.649	13.982	X	ABQ
SLC	13.716	14.049	X	SLC
PHL	13.763	14.096	2	PHL
FAT	13.763	14.096	3	FAT
MCO	13.816	14.149	X	MCO
HOU	13.832	14.165	5	HOU
LGA	13.843	14.176	X	LGA
SHV-BTR-MOB	13.883	14.216	3	Shvbtrmob
MAF	13.889	14.222	5	MAF
HOU	13.915	14.248	X	HOU
LAS	13.916	14.249	X	LAS
DEN	13.936	14.269	3	DEN
HRL	13.969	14.302	4	HRL
SAT	14.132	14.465	5	SAT
DTW	14.166	14.499	X	DTW
BDL	14.233			
SAT	14.245	14.578	X	SAT
MEM	14.289	14.622	4	MEM
OAK	14.313			
TUL	14.332	14.665	5	TUL
LIT	14.392	14.725	X	LIT
ATL	14.416	14.749	3	ATL
JAC-LBB	14.416	14.749	4	JAC-LBB
ORD	14.416	14.749	X	ORD
TUL	14.465	14.798	X	TUL
LGA	14.513			
SAN	14.766	15.099	X	SAN
MIA	14.816	15.149	X	MIA
STL	14.839	15.172	X	STL
LGA	14.843	15.176	X	LGA
AUS	14.855	15.188	7	AUS

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
SJC	14.913			
HOU	14.915	15.248	X	HOU
ONT	14.916	15.249	X	ONT
IND	14.946	15.279	3	IND
MCI	14.999	15.332	4	MCI
ELP	15.009	15.342	4	ELP
BOS	15.033			
TUS	15.066	15.399	3	TUS
RDU	15.066	15.399	X	RDU
CVG	15.136	15.469	3	CVG
DCA	15.166	15.499	X	DCA
DEN	15.189	15.522	X	DEN
MSY	15.249	15.582	5	MSY
PVR-GDL	15.249	15.582	5	PVR-GDL
SFO	15.313			
ICT	15.332	15.665	5	ICT
AMA	15.532	15.865	6	AMA
PHX	15.546	15.879	4	PHX
OKC	15.575	15.908	6	OKC
OKC	15.588	15.921	X	OKC
ORD	15.666			
DAY	15.666			
ATL	15.749	16.082	X	ATL
YYC	15.753			
LAX	15.766	16.099	X	LAX
MIA	15.816	16.149	X	MIA
SNA	15.816	16.149	X	SNA
CRP	15.832	16.165	6	CRP
MCI	15.832	16.165	X	MCI
HNL	15.91			
JAX	15.846			
CUN	15.959	16.292	4	CUN
LGA	16.013			
BWI	16.016	16.349	X	BWI
RDU	16.066	16.399	X	RDU
MEX	16.086			
MSP	16.086			
TPA	16.086			
SJU	16.113			
DCA	16.166	16.499	X	DCA
DEN	16.189	16.522	X	DEN
BHM	16.199	16.532	4	BHM
LGA	16.263			

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
CMH	16.266			
RNO	16.316	16.649	X	RNO
HOU	16.415	16.748	6	HOU
ORD	16.416	16.749	XY	ORD
BNA	16.439			
HOU	16.498	16.831	X	HOU
LGA	16.513			
ABQ	16.599			
CLT	16.686			
MFE-MTY	16.686			
GSO	16.746			
LAX	16.766	17.099	X	LAX
SAT	16.775	17.108	6	SAT
TUS	16.799	17.132	X	TUS
HSV	16.839			
SAT	16.888	17.221	X	SAT
RSW	16.916			
COS	16.999			
OMA	16.999			
TUL	17.015	17.348	6	TUL
PHL	17.016	17.349	X	PHL
MCO	17.096			
MAF	17.132	17.465	6	MAF
TUL	17.148	17.481	X	TUL
SLC	17.166			
DCA	17.166	17.499	X	DCA
AUS	17.178	17.511	8	AUS
LAS	17.216			
HRL	17.232			
PHX	17.359	17.692	X	PHX
CLE	17.362	17.695	X	CLE
SMF	17.4			
BNA	17.452	17.785	X	BNA
HOU	17.498	17.831	X	HOU
ORD	17.499	17.832	X	ORD
DTW	17.516			
MEM	17.632			
ABQ	17.632	17.965	X	ABQ
LIT	17.655	17.988	X	LIT
LAX	17.766	18.099	X	LAX
CLE	17.936			
DSM	17.959			
STL	17.959			

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
MEX	17.989	18.322	X	MEX
MSP	17.989	18.322	X	MSP
TPA	17.989	18.322	X	TPA
PHL	18.016	18.349	X	PHL
OKC	18.018			
PBI	18.116			
LIT-JAN	18.116			
ICT	18.215			
SAN	18.236			
PDX	18.2			
MIA	18.296			
DEN	18.359			
ONT	18.416			
AMA	18.455			
ORD	18.499	18.832	X	ORD
ELP	18.532			
SEA	18.58			
MCI	18.582			
RDU	18.596			
ORF	18.646			
PIT	18.7			
DCA	18.7			
CRP	18.815			
MSY	18.832			
PVR-GDL	18.832			
FLL	18.836			
HOU	18.998			
ATL	18.999			
JAC-LBB	18.999			
ORY	19.09			
STL	19.162	19.495	X	STL
LAX	19.186			
SNA	19.246			
YYZ	19.246			
LGB	19.366			
SAT	19.418			
BWI	19.486			
AUS	19.501			
MAD	19.59			
BUR	19.666			
TUL	19.698			
DCA	19.716			
CUN	19.782			

Airport (FROM)	Arrival Time	Dprt Time	Code	Airport (TO)
IND	19.789			
RNO	19.846			
TUS	19.949			
CVG	20.01			
BHM	20.15			
BFL	20.18			
RIC-SDF	20.2			
PHL	20.686			
FAT	20.686			
MAF	20.375			
PHX	20.589			
SHV-BTR-MOB	20.866			

BIOGRAPHICAL SKETCH

Trace Arley Weisenburger was born in Missoula, Montana, on April 24, 1968. He received his elementary education in the Emma Dickinson Elementary Public School. His secondary education was completed at Big Sky High School in the Missoula County School District. In 1986, he entered the United States Air Force Academy and was awarded a Bachelor of Science in Civil Engineering in 1990. In August of 1990, he attended undergraduate pilot training at Williams Air Force Base graduating in 1991 with a Certificate of Aeronautical Rating. In January 1992, he entered the graduate College at Arizona State University in the field of Civil Engineering.